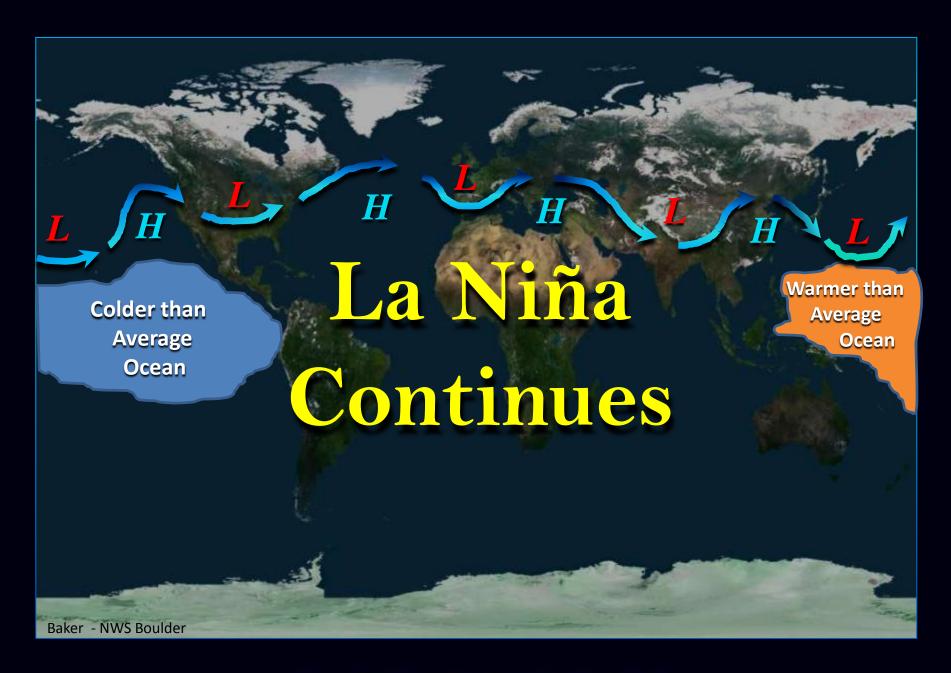
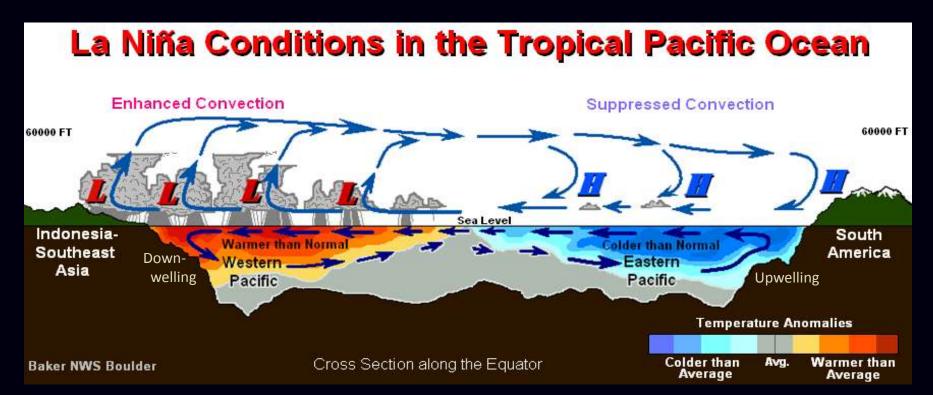
La Niña, MJO
and the
January-March 2012
Outlook
For Denver and
the Rest of Colorado

Mike Baker
National Weather Service
Boulder, Colorado
December 22, 2011









La Niña Advisory

The atmospheric and oceanic circulations in the equatorial region of the Pacific Ocean during November and December of 2011 were indicative of a weak to moderate La Niña. These circulations include enhanced/suppressed convective (thunderstorm development) over the western/eastern tropical Pacific Ocean, respectively, low-level easterly and upper level westerly wind anomalies along the Equator, and anomalously strong easterly sub-surface ocean currents which enhanced upwelling (cooling) in the eastern tropical Pacific and downwelling (warming) in the western tropical Pacific Ocean (refer to these circulations in the above diagram).

These conditions are not expected to achieve the degree of magnitude observed last winter during a moderate to strong La Niña.

The Oceanic Niño Index - ONI

Year	DJF	JFM	FMA	МАМ	АМЈ	МЈЈ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.6	-1.4	-1.0	-0.8	-0.6	-0.5	-0.4	-0.4	-0.4	-0.5	-0.6	-0.7
2001	-0.6	-0.5	-0.4	-0.2	-0.1	0.1	0.2	0.2	0.1	0	-0.1	-0.1
2002	-0.1	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.1	1.3	1.5	1.4
2003	1.2	0.9	0.5	0.1	-0.1	0.1	0.4	0.5	0.6	0.5	0.6	0.4
2004	0.4	0.3	0.2	0.2	0.3	0.5	0.7	0.8	0.9	0.8	0.8	0.8
2005	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.2	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.1	0.1	0.2	0.3	0.5	0.6	0.9	1.1	1.1
2007	0.8	0.4	0.1	-0.1	-0.1	-0.1	-0.1	-0.4	-0.7	-1.0	-1.1	-1.3
2008	-1.4	-1.4	-1.1	-0.8	-0.6	-0.4	-0.1	0	0	0	-0.3	-0.6
2009	-0.8	-0.7	-0.5	-0.1	0.2	0.6	0.7	0.8	0.9	1.2	1.5	1.8
2010	1.7	1.5	1.2	0.8	0.3	-0.2	-0.6	-1.0	-1.3	-1.4	-1.4	-1.4
2010	1./	1.5	1.2	0.0	0.5	0.2	0.0	1.0	1.5	2.7	2.7	
2011	-1.3	-1.2	-0.9	-0.6	-0.2	0	0	-0.2	-0.4	-0.7		

1

El Niños (warm phase events): ONI of +0.5 and higher (red numbers)

La Niñas (cold phase events): ONI of -0.5 and lower (blue numbers)

ENSO-Neutral (near normal conditions): ONI below +0.5 and above -0.5 (black numbers)

An ONI of -0.7 is an indication of weak La Niña conditions in the tropical Pacific Ocean during the SEP-OCT-NOV 2011 climate season.

The ONI is based on sea surface temperature (SST) departures from average in the Niño 3.4 region of the eastern tropical Pacific Ocean. It is the principal measure used by NOAA's Climate Prediction Center (CPC) for monitoring, assessing and predicting El Niño/Southern Oscillation (ENSO.)

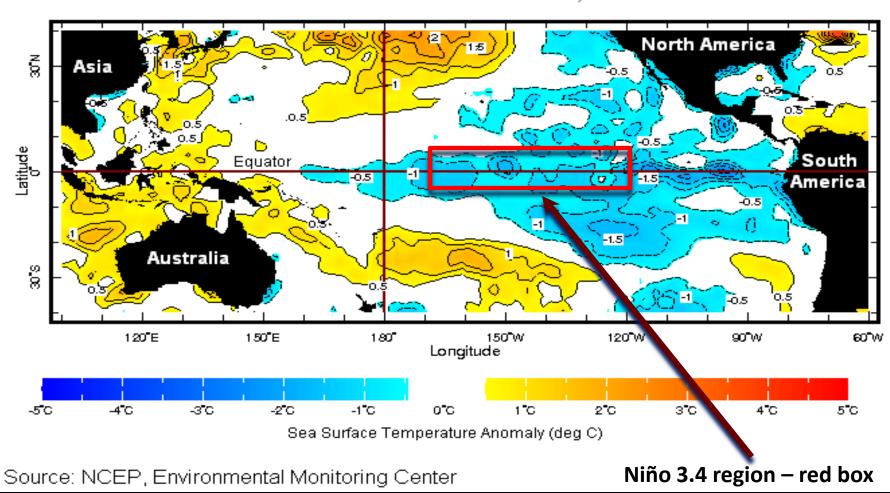
ONI is defined as the threemonth running-mean SST departures in the Niño 3.4 region.

ONI is used to place current ENSO and non-ENSO events into a historical perspective.

CPC's operational definitions of El Niño and La Niña are keyed to the ONI index.

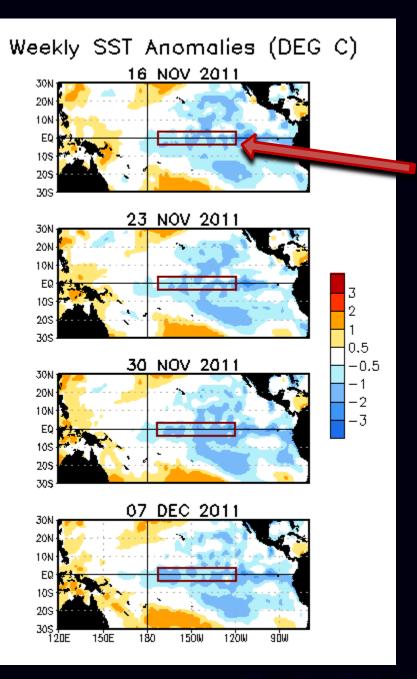
NOAA/CPC Dec 15 2011

Weekly Sea Surface Temperature Anomalies (deg C) For the Week of Dec 4-10, 2011

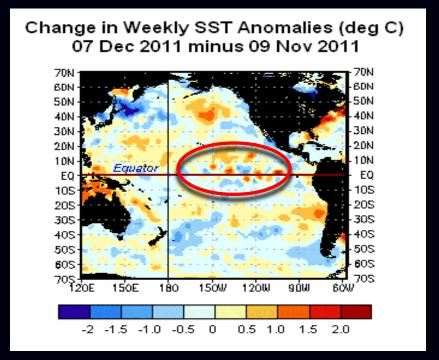


Below average sea surface temperatures (SST) were evident across the central and eastern tropical Pacific Ocean during this period, with positive SSTs anomalies in a horse shoe pattern from the south-central Pacific Ocean to the western Pacific around Indonesia, and across the northern Pacific Ocean to the western tip of Alaska.

Baker - National Weather Service Boulder, Colorado

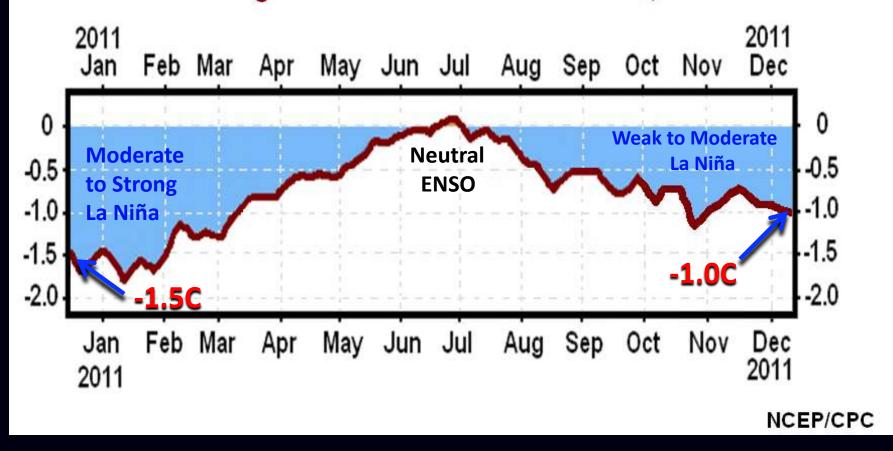


During the last four weeks (16 Nov to 07 Dec, 2011), equatorial sea surface temperatures remained below average across the eastern two-thirds of the Pacific Ocean. (The red box denotes the Niño 3.4 region in the tropical eastern Pacific Ocean.)

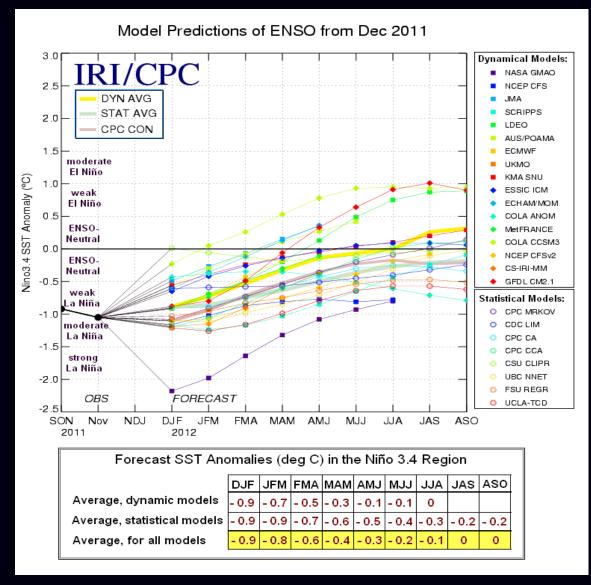


During this 30 day period, local, rather than large-scale, changes in SST anomalies were observed across the eastern tropical Pacific Ocean.

Sea Surface Temperature Anomaly (°C) for the Equatorial Pacific Region Niño 3.4 as of December 7, 2011



As of 7 December, 2011 the weekly SST anomaly for Niño 3.4 was -1.0C. One year ago on this date, the SST anomaly for Nino 3.4 Region was -1.5C.

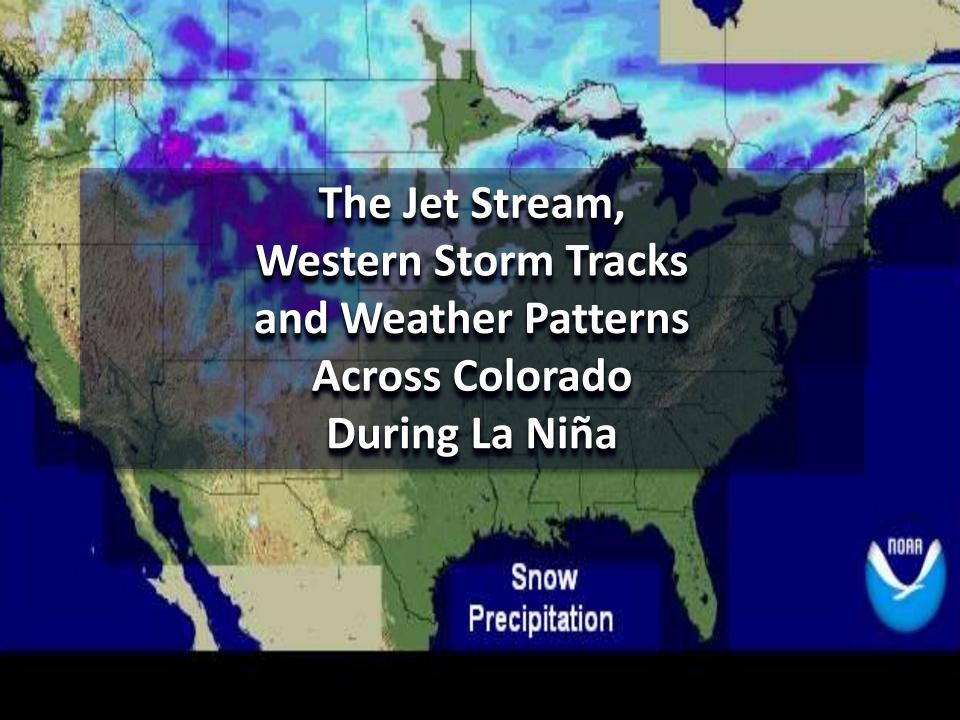


Source: International Research Institute for Climate and Society (IRI) – updated Dec 15 2011

Since September of 2011, La Niña conditions have prevailed in the Pacific Ocean.

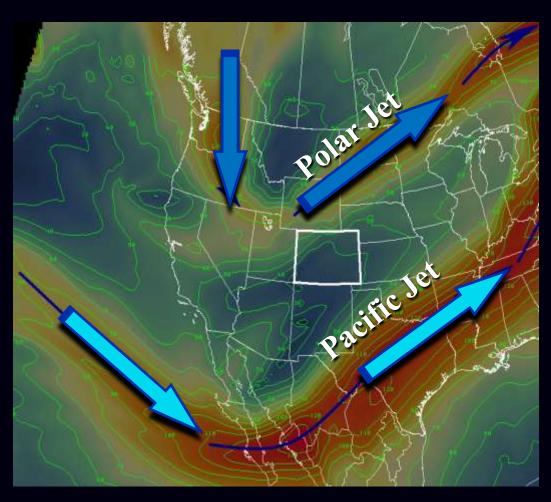
Approximately half of the dynamical and statistical ENSO models predict weak La Niña conditions, and the remaining half of these models, including NCEP's Coupled System Forecast Model (CFS), predict a moderate La Niña at least through the northern hemisphere winter of 2011-2012.

One model, NASA's Global Modeling and Assimilation Office (GMAO) model, goes so far as to predict a strong La Niña for this winter. However, current observational data largely does not support this outlier.



The Jet Stream

- A channel of strong winds within the Westerly Wind Belt (30-60° N latitude)
- Produced by large pressure and temperatures gradients between the poles and the Equator
- May be thousands of miles long, hundreds of miles wide, and thousands of feet deep
- Typically found between 20,000 and 35,000 feet ASL; sometimes lower in altitude during the winter months.
- Wind speeds may exceed 180 mph
- Its location can vary widely from week to week and even day to day.
- Much of the variability we see in precipitation, temperature, wind and cloud cover, particularly during the winter and spring, can be attributed to the Polar and Pacific jet streams.



Model Depiction of the Polar and Pacific Jet Streams

Typical Jet Stream Pattern During La Niñas



During La Niñas, mainly moderate to strong events, the Pacific jet stream will typically round the top of large upper level high pressure ridges positioned along the west coast of the U.S. often for weeks at a time. From there the jet will typically dive southeast over the central Rocky Mountains along a path similar to the one depicted in the adjacent illustration.

Typical Jet Stream Pattern During El Niños



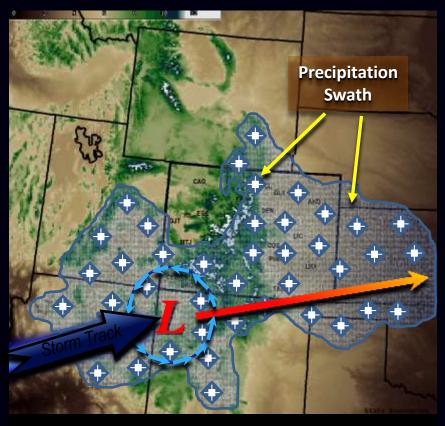
During El Niños, mainly moderate to strong events, the Pacific jet stream normally shifts south down the west coast often rounding the bottom of an upper level low pressure trough anchored over the southwest U.S. From here the jet meanders eastward over the Desert Southwest and southern Rocky Mountain region along a path similar to the one depicted in the adjacent illustration.

Northwest Storm Track

Precipitation Swath

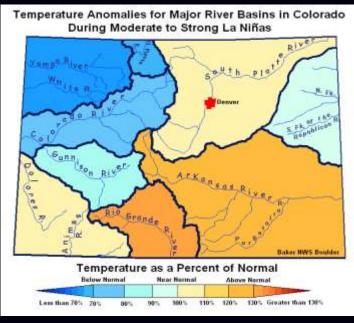
Pacific storm systems following a path similar to the one depicted in the above illustration tend to produce their greatest precipitation/snowfall over the mountainous terrain of northern Utah, western Wyoming and northwestern Colorado. Often these fast moving storms are accompanied of strong winds capable of producing blizzard-like conditions on the higher mountain passes and ridges.

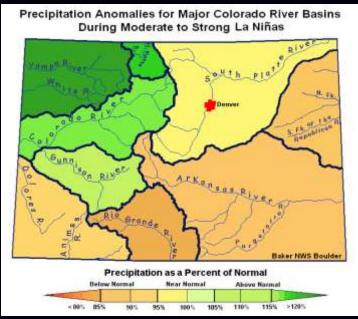
Southwest Storm Track



Pacific storms tracking northeast out of the desert southwest along a path similar to the one above is likely to produce the greatest precipitation/snowfall over the mountainous terrain of northeast Arizona, northern and western New Mexico, southern Utah, and southwest and south central Colorado. These often slow moving storms are also capable of producing blizzard-like conditions on the high plains.

Baker - National Weather Service Boulder, Colorado

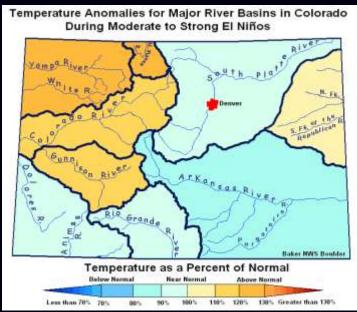


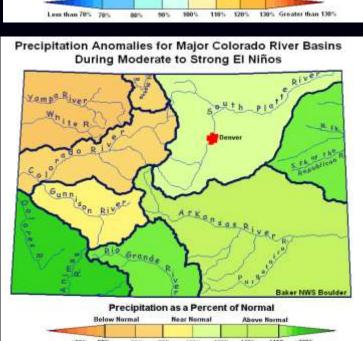


During La Niña Winters

Temperatures — are typically <u>below average</u> across northwest, west central and north central Colorado and <u>above average</u> across southern and most of eastern Colorado during La Niñas of moderate to strong intensity. It is far less likely to see this temperature anomaly pattern during weak La Niña events, except perhaps during extended periods of west-northwest flow aloft.

Precipitation/snowfall — is typically above to much above average across northwest, west central and north central Colorado, and below to much below average across southern and eastern portions of the state during La Niña events of moderate to strong intensity. This precipitation anomaly pattern is far less evident during weak La Niñas, however there is a history of this pattern developing with a persistent west-northwest flow aloft.





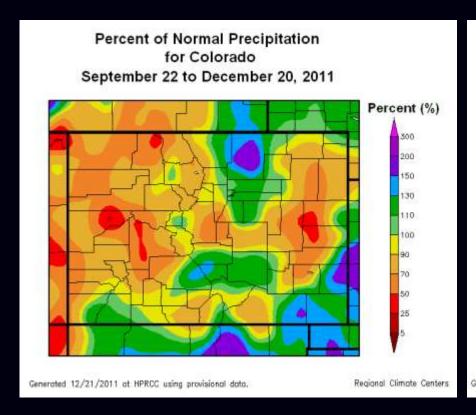
During El Niño Winters

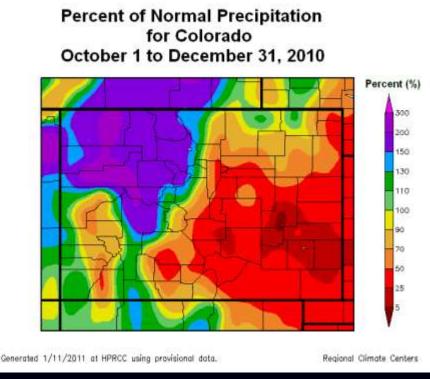
Temperatures — are typically <u>above average</u> across northwest, west central and north central Colorado and <u>below average</u> across southern and most of eastern Colorado during La Niñas of moderate to strong intensity. It is less likely to see this cross state temperature anomaly pattern during weak La Niñas, expect perhaps during extended periods of west-northwest flow aloft.

Precipitation/snowfall — has historically been above to much above average across northwest, west central and north central Colorado, and below to much below average across southern and eastern Colorado during La Niña events of moderate to strong intensity. This precipitation anomaly signal was less evident during weak La Niñas, however there was a tendency to see this pattern during extended periods of northwest flow aloft.



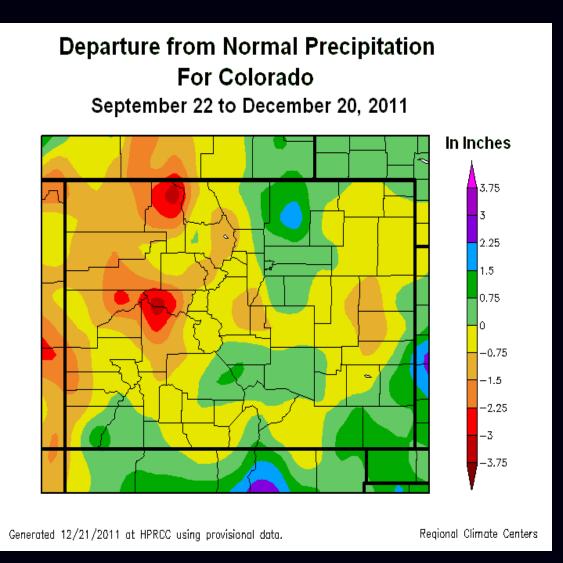
Temperature, Precipitation, and Drought **Conditions Across Colorado** During the 90-Day Period September 22 to December 20, 2011





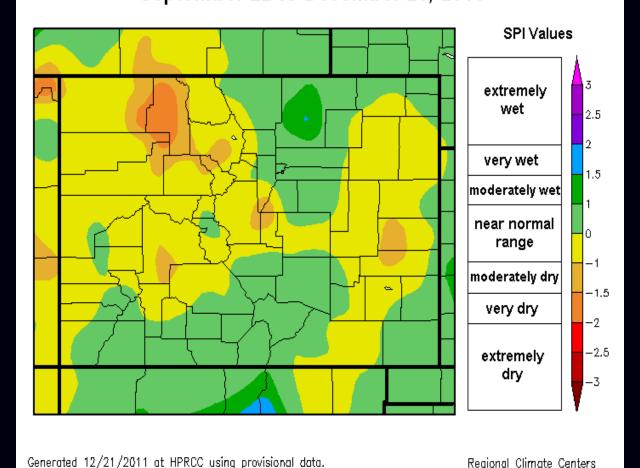
During the 90-day period ending December 20, 2011, precipitation totals across Colorado ranged from as little as 25 percent of normal for a number of locations in western Colorado, to as high as 200 percent of normal along the Front Range in northeast Colorado and in lower portions of the Arkansas River Valley near the Kansas border. Generally speaking, areas east of the Continental Divide were generally wetter/snowier than areas west of the Divide.

The distribution of precipitation this autumn was in stark contrast to the distribution pattern observed last autumn (refer to the map in the upper right.)



During this 90-day period, precipitation departures across Colorado ranged from around 4 inches below normal along the west facing slopes of the Park and Gore mountain ranges in north central Colorado and along the west facing slopes of the Elk and West Elk ranges in west central Colorado, to around 2 inches along the eastern slope of the Front Range in northeast Colorado. Once again, areas west of the Continental Divide were noticeably drier than areas east of the Divide, especially in those areas subject to frequent bouts of drying easterly downslope winds such as along the Gore and Elk ranges around Steamboat Springs and Aspen, respectively.

90 Day Standardized Precipitation Index (SPI) for Colorado September 22 to December 20, 2011



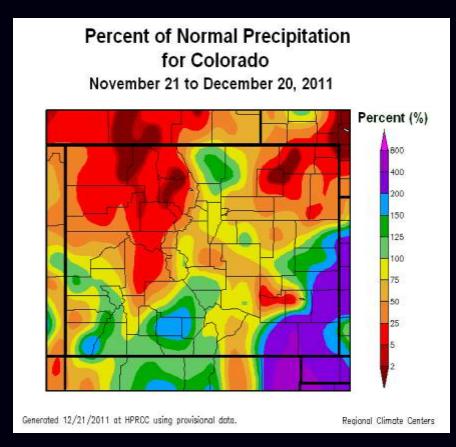
The Standardized Precipitation Index (SPI) for

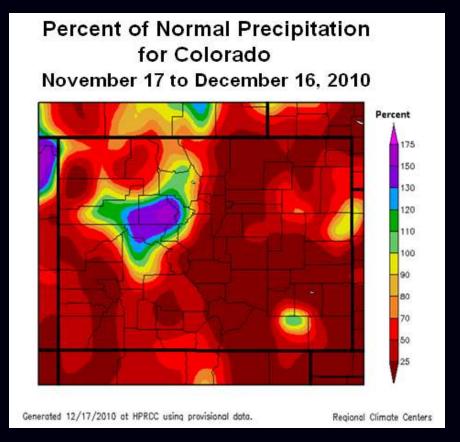
this 90-day period indicates near normal to very dry conditions across much of western Colorado, as well as portions of the state's southeast plains, and near normal to moderately wet conditions along the state's southern border and much of the eastern plains.

The SPI was developed to monitor potential short term agricultural and long-term hydrological drought conditions. The SPI is a probability index that considers <u>only</u> precipitation.

20	11	Λ	OVEN	201	L			
Su	2011		2011					
	Sunday	Monday	Yonday Zuesday Wednesday J			Thursday Leiday		
•					1	2	3	
1	4	5	6	7	8	9	10	
	11	12	13	14	15	16	17	
_	18	19	20	21	22	23	24	
Baker	25	26	27	28	29	30	31	
	Baker NWS Boulder							

Temperature, Precipitation, and Drought **Conditions Across Colorado** During the 30-Day Period November 21 to December 20, 2011

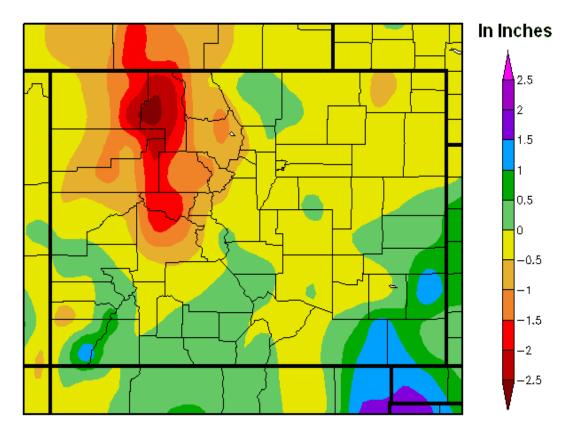




During the 30-day period ending 20 December, 2011, precipitation amounts across south central and southeast Colorado were well above normal; as much as 600 to 800 percent of normal in the southeast! This impressive statistic is largely due to a recent blizzard that deposited upwards of two feet of snow in the area. In contrast, much of northwest and parts of northeast Colorado saw significantly less precipitation; in parts of the northwest and north central mountain valleys as little as 5 percent of normal! Again, this was a dramatic reversal from the pattern observed one year ago when a strong and persistent northwest flow ushered in waves of heavy snow and strong winds to northwest Colorado, and produced frequent bouts of abnormally warm and very dry downslope winds east of the mountains. (Note this obvious difference in last year's precipitation on the map in the upper right.)

Departure from Normal Precipitation for Colorado

November 21 to December 20, 2011



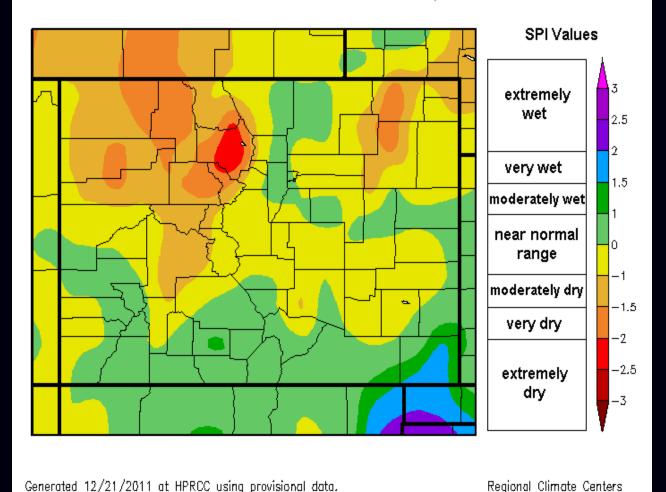
Generated 12/21/2011 at HPRCC using provisional data.

Regional Climate Centers

During the 30-day period ending December 20, 2011, precipitation departures across Colorado varied widely from near 1.5 inches in southeast Colorado and southern slopes of the San Juan Mountains in southwest Colorado, to an impressive 2 to 3 inches below normal in northwest and west central Colorado, generally along the western exposures of the Gore, Park, Elk and Wet Elk mountain ranges.

A significant shift in the large scale wind pattern and storm track set the stage for this dramatic reversal in precipitation across Colorado. A persistent storm track across New Mexico and southern Colorado kept precipitation largely confined to these areas.

30 Day Standardized Precipitation Index (SPI) for Colorado November 21 to December 20, 2011

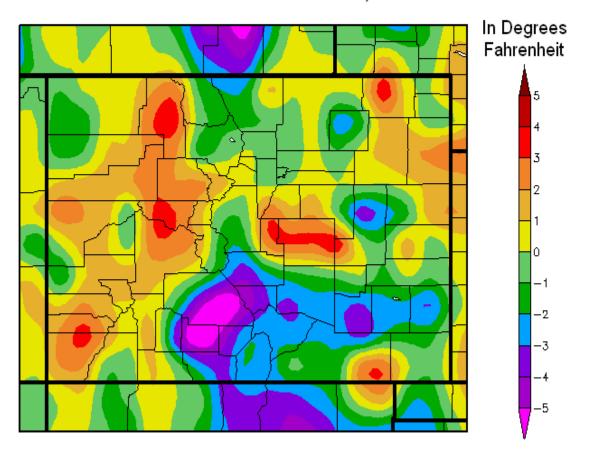


Moisture levels across
Colorado during this 30day period, according to
the SPI, were near
normal to moderately
dry across northern
Colorado, and near
normal to very wet
across the southern half
of the state.

Most notable was the bulls eye of extremely dry conditions in the upper portions of the Colorado River Basin, particularly in Grand County, where soil conditions were determined to be extremely dry.

Departure from Normal Temperature for Colorado

November 21 to December 20, 2011

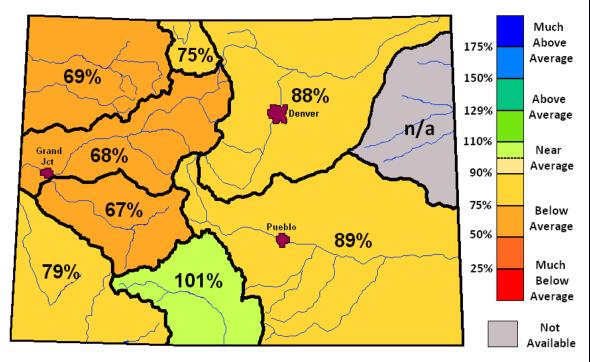


Generated 12/21/2011 at HPRCC using provisional data.

Regional Climate Centers

Temperatures across Colorado during the 30day period ending December 20, 2011, varied widely across the state. Temperatures ranged from 3 to 5 degs $(\Box F)$ below normal in parts of the south and southeast, to around 3 degs (□F) above normal in east central Colorado around Colorado Springs and portions of the northwest and west central Colorado. The lack of precipitation and snow cover in this region no doubt had a significant influence on temperatures.

Colorado SNOTEL Snowpack Update Map



Snow Water Equivalent as a Percent of Average (%) for Colorado by River Basin as of Thursday December 22, 2011

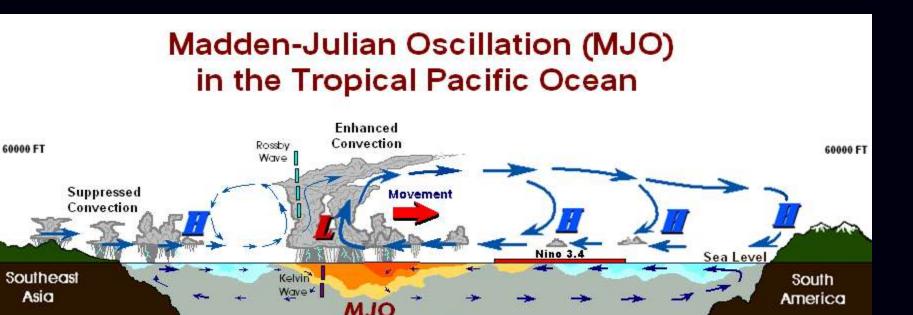
Basin Wide Percent of Average (%)

WEST SLOPE	EAST SLOPE
Yampa and White River Basins	Laramie & North Platte Basin
San Miguel, Dolores, Animas & San Juan River Basins	Statewide Avg77%

Source: USDA Natural Resources Conservation Service--Water and Climate, Portland, Oregon provisional data, subject to revision

Snowpack in Colorado as of December 22, 2011 was below average for all except the San Luis Valley in south central Colorado where the latest snowpack measurement was about average.

The predominant storm track during the past several weeks favored precipitation/ snowfall production across southern and eastern portions of the state—a common pattern observed during El Niño conditions. This autumn, MJO played an important role in the weather across Colorado, even in the midst of a weak to moderate La Niña.



Temperature Anomalies

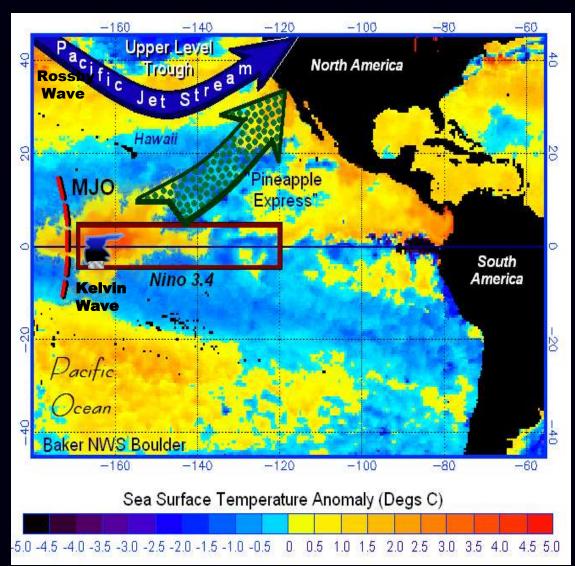
Colder than Avg. Warmer than

Average

Interseasonal variations in wind and temperature produced by the 30-60 Day Tropical Wave, also known as the Madden-Julian Oscillation (MJO), can have a significant influence on global atmospheric and oceanic circulations. The time it takes for most MJO Kelvin and Rossby waves to circle the Earth along the Equator varies from 30 to 60 days with the average about 45 days. Strong MJO activity is most likely to occur during weak La Niña events and ENSO-neutral conditions, with weak to absent activity during moderate to strong El Niño episodes. MJO circulations within the equatorial region of the eastern Pacific Ocean can have a significant impact on weather patterns in Hawaii and across the western continental United States. These variations include departures from normal in temperature, wind and precipitation not unlike those observed during moderate to strong El Niños, but for shorter periods of time.

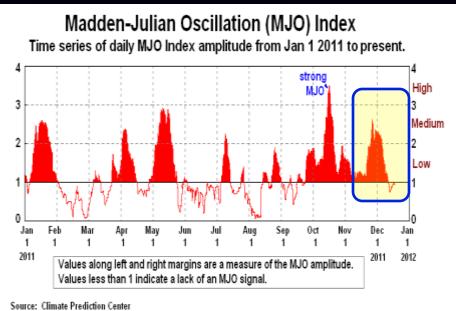
Cross section drawn along the Equator

Baker NWS Boulder

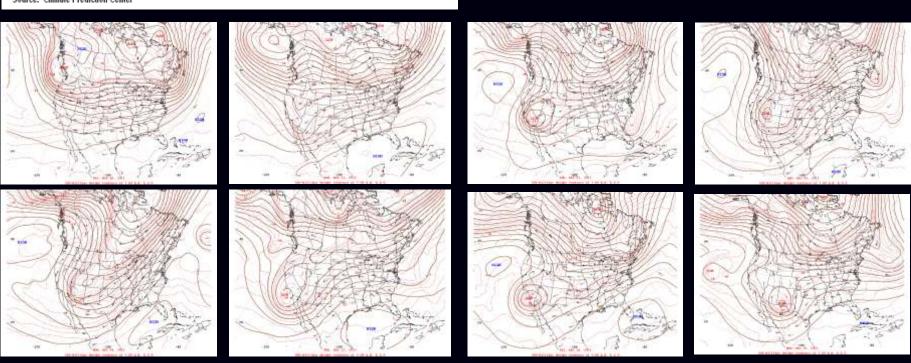


Deep tropical convection or thunderstorm activity along the Intertropical Convergence Zone (ITCZ) is enhanced by the anomalous warming of sea waters by means of subduction in advance of these eastward propagating MJOs or oceanic tropical waves.

As the Kelvin wave and its deep convection travel eastward through the Niño 3.4 region in the eastern Pacific, broad circulation around the bottom side of the Rossby wave or upper level mid-latitude trough coupled to the Kelvin wave transports a steady stream of moisture rich tropical air northeastward up into middle latitudes via the subtropical jet stream ("Pineapple Express"). Feeling the effects of this tropical connection first is Hawaii, then the western U.S. as the MJO continues its eastward progress across the Niño 3.4 region. Effects commonly include a period of anomalously heavy precipitation for each of these areas.



The Madden-Julian Oscillation Index peaked again in late November and early December of 2011. During this period, several upper level midlatitude troughs (Rossby waves) formed or passes over the western U.S., and in many instances persisted for several days at a time. This upper air pattern resulted in several periods of light to moderate precipitation, and in some areas heavy precipitation, across the southwest U.S. including southern and eastern Colorado; a pattern commonly associated with El Niño cycles.

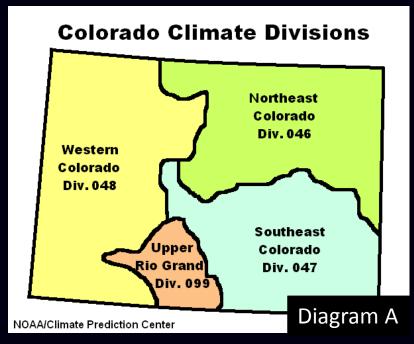


Baker - National Weather Service Boulder, Colorado



A majority of the storm systems that forms over and/or propagated across the western continental U.S. during November and December followed paths that carried them south of Colorado. This southern storm track pattern was largely responsible for the abnormally low precipitation/snowfall amounts observed across west central, northwest and north central Colorado during the period.





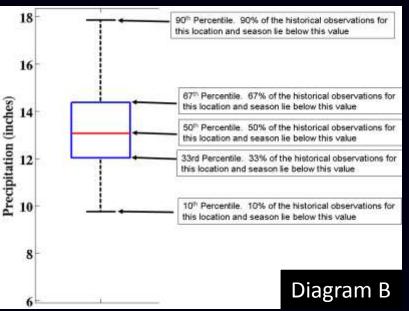


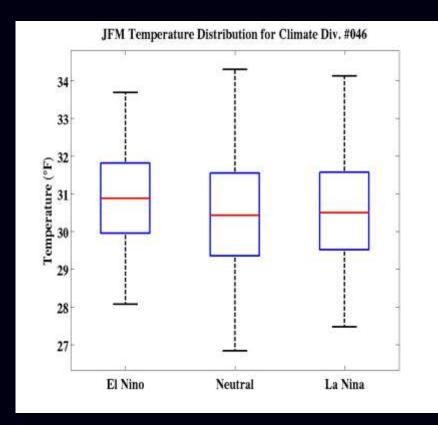
Diagram A depicts the four CPC climate megadivisions in Colorado. Climate divisions 046, 047 and 099 are located on the east side of the Continental Divide, while division 048 is situated on the state's western slope.

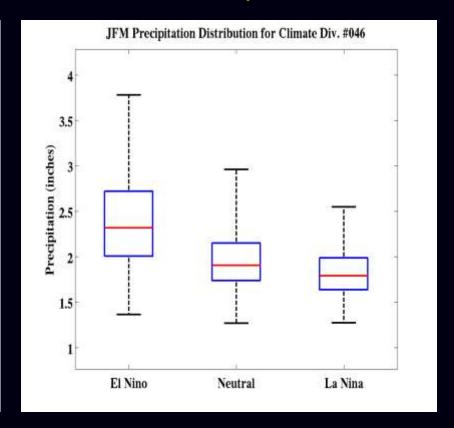
CPC has produced historical 3-month temperature and precipitation distributions associated with three different ENSO categories –El Niño, La Niña and neutral (non-ENSO) conditions – for each climate division in the United States.

Diagram B depicts and describes the ENSO box and whisker analysis plots used by CPC to present these historical temperature and precipitation distributions.

The red line inside the ENSO box represents the mean or 50th percentile of the data (temperature or precipitation) distribution for each climate division. Approximately 34% of the total observations exist within the ENSO box, and the remaining observations (about 66%) lie outside of the box along the whiskers extending above and below the box.

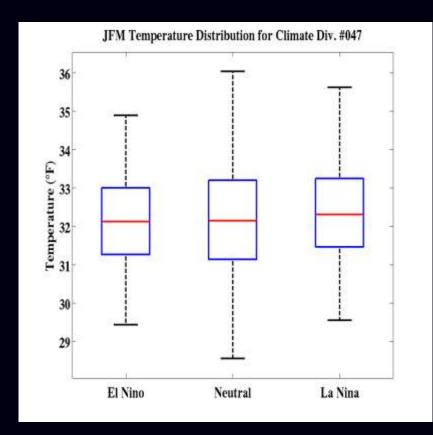
ENSO Box and Whisker Analysis Plots for the Northeast Colorado Climate Division #046 for the 3-Month Season January-March

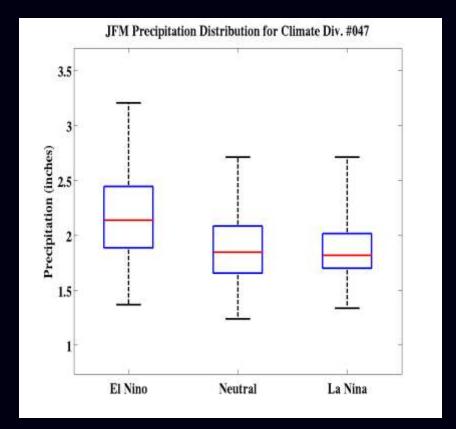




Historically, temperatures for northeast Colorado during the months of January-February-March were nearly identical during La Niña and non-ENSO periods, and only slightly warmer during El Niño events. Precipitation for northeast Colorado during this three month period was determined to be greatest during El Niño episodes and least during La Niña events, with ENSO-neutral periods only slightly better.

ENSO Box and Whisker Analysis Plots for the Southeast Colorado Climate Division #047 for the 3-Month Season of January-March

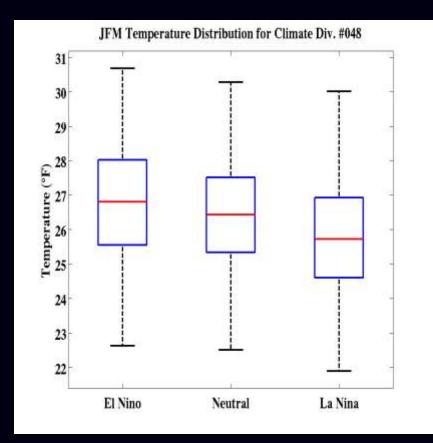


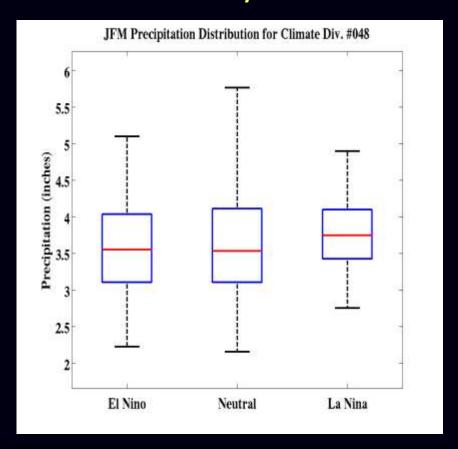


Temperatures for southeast Colorado during January-February-March were nearly similar for ENSO and ENSO-neutral periods, although there was a slight bias towards warmer temperatures during La Niña events.

Precipitation for southeast Colorado for the same three month period had a tendency to be warmer during El Niño events and were generally similar during ENSO-neutral and La Niña events.

ENSO Box and Whisker Analysis Plots for the Western Colorado Climate Division #048 for the 3-Month Season of January-March





Temperatures for western Colorado during January-February-March have historically been warmest during El Niño and coolest during La Niña events.

Precipitation for western Colorado during the same three month period was nearly similar during ENSO and ENSO neutral periods, although there was a bias towards higher precipitation during past La Niña events.

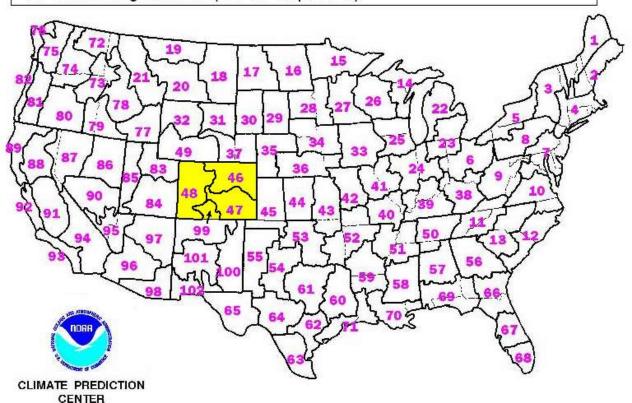
January- March 2012
Temperature and Precipitation
Outlook for Colorado
Issued by NOAA's
Climate Prediction Center

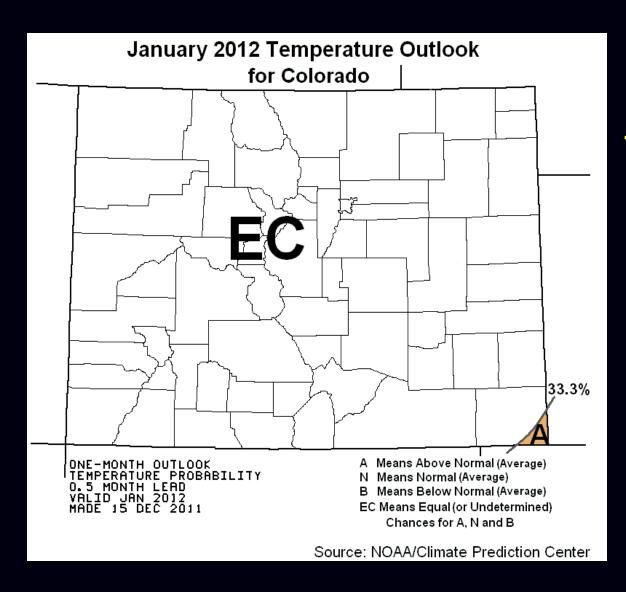
Climate Prediction Center Seasonal Outlooks

The National Weather Service Seasonal Climate Outlooks predict the probability of conditions being among the warmest/coldest or wettest/driest terciles of years compared to the period of record 1981-2010.

The outlooks indicate probability of being in three specific categories in reference to the 30-year climatology from 1981-2010. They are above, below and average.

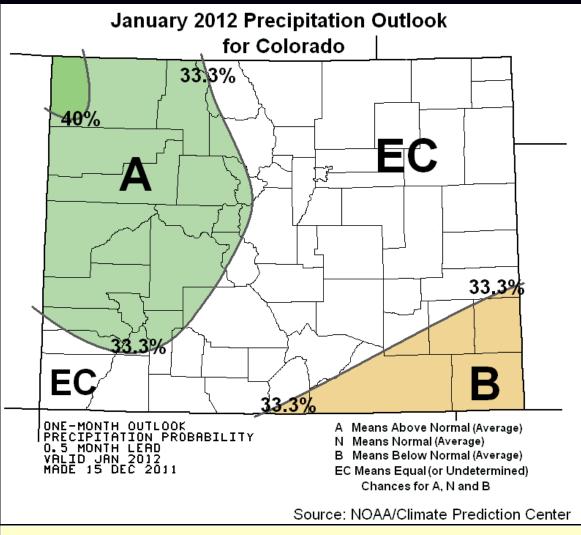
Remember, Climate Predicition Center (CPC) outlooks are made at the scale of the climate megadividions (see the map below).





January 2012 Temperature Outlook for Colorado

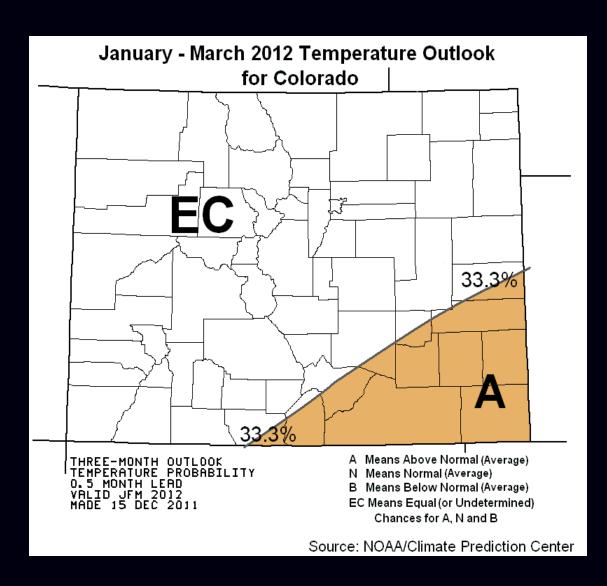
The latest one-month temperature outlook from NOAA's Climate Prediction Center (CPC) calls for an equal (or undeterminable) chance of above, below and near average temperatures essentially for all of Colorado during the month of January.



This probabilistic shift to above normal precipitation across northwest Colorado may be an indication of a potential large scale shift to a jet stream and weather pattern commonly associated with La Niña.

January 2012 Precipitation Outlook for Colorado

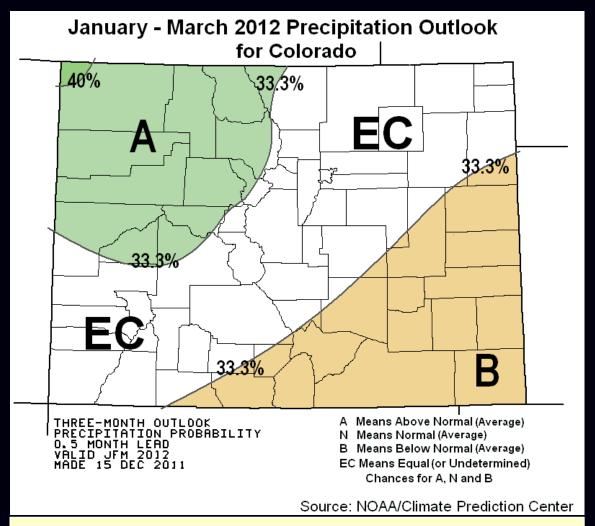
The outlook for January calls for at least a 33.3% chance for above average precipitation across northwest and west central Colorado, and at least a 33.3% chance for below average precipitation in the southeast corner of the state. For the reminder of the state, the outlook calls for an equal (or undeterminable) chance of above, below and near average precipitation during January.



January-March 2012 Temperature Outlook for Colorado

The 3-month temperature outlook from CPC calls for an equal (or undeterminable) chance of above, below and near average temperatures for all except the southeast corner of Colorado during the period January-March of 2012.

For the southeast corner of the state, odds are that temperatures during this period will be above average.



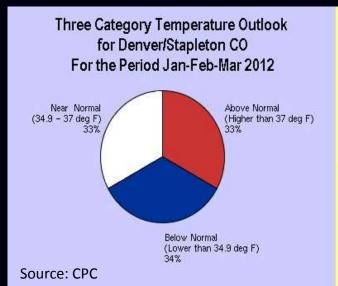
The probabilistic shift to above normal precipitation across northwest Colorado during January is also carried through to March as per this latest outlook from CPC. A return to La Niña conditions in the absence of an MJO may account for this pattern change.

January-March 2012 Precipitation Outlook for Colorado

Last but not least, the latest 3-month precipitation outlook from CPC calls for above average precipitation (at least a 33.3% chance) across the northwest quarter of Colorado, and below average precipitation (at least a 33.3% chance) across the southeast corner of the state during the period January-March of 2012.

For the remainder of the state, CPC is calling for an equal (or undeterminable) chance of above, below and near average precipitation during this three month period—as indicated by the EC symbol.

Three Category Temperature Outlooks For Four Locations in Northeast Colorado

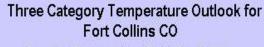


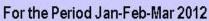
There is a 33.0% chance for the average temperature during this 3month period to be higher than 37.0°F.

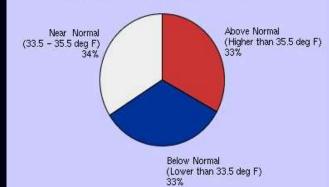
There is a 33.0% chance for the average temperature during the 3month period to be between 34.9°and 37.0°F.

There is a 34.0% chance for the average temperature during this 3month period to be lower than 34.9°F.

Based on the 1981-2010 climatological reference period







Source: CPC

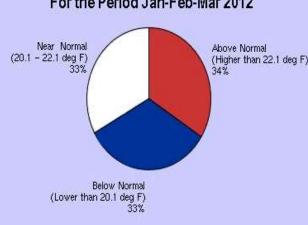
There is a 33.0% chance for the average temperature during this 3month period to be higher than 35.5°F.

There is a 34.0% chance for the average temperature during the 3month period to be between 33.5° and 35.5°F.

There is a 33.0% chance for the average temperature during this 3month period to be lower than 33.5°F.

Based on the 1981-2010 climatological reference period

Three Category Temperature Outlook for Dillion CO For the Period Jan-Feb-Mar 2012



Source: CPC

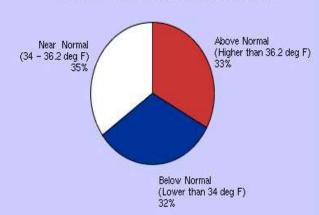
There is a 34.0% chance for the average temperature during this 3month period to be higher than 22.1°F.

There is a 33.0% chance for the average temperature during the 3month period to be between 20.1° and 22.1°F

There is a 33.0% chance for the average temperature during this 3month period to be lower than 20.1°F

Based on the 1981-2010 climatological reference period

Three Category Temperature Outlook for Sterling CO For the Period of Jan-Feb-Mar 2012



Source: CPC

There is a 33.0% chance for the average temperature during this 3month period to be higher than 36.2°F.

There is a 34.0% chance for the average temperature during the 3month period to be between 34.0° and 36.2°F.

There is a 32.0% chance for the average temperature during this 3month period to be lower than 34.0°F

Based on the 1981-2010 climatological reference period

Summing It Up...

- Climate models are predicting a continuation of the weak to moderate La Niña through the end of the 2011-2012 winter season, then a gradual transition to ENSO-neutral conditions during the spring of 2012.
- During previous La Niñas, winter time precipitation for Colorado was typically below average for western and northwestern parts of the state, and near to below average for southern and eastern portions of Colorado. Furthermore, winter time temperatures were generally colder than average across northwest and north central Colorado, and near to above average for the remainder of the state.
- During this past autumn, the usual effects of La Niña on Colorado weather were muted possibly by interseasonal variations in temperature and precipitation associated with a couple of well organized tropical waves or Madden-Julian Oscillations that propagated eastward across the eastern tropical Pacific Ocean during the period.
- The latest outlook from the Climate Prediction Center calls for better than a 33.3% chance for above average precipitation across west central and northwest Colorado and the same odds for near to below average precipitation for the remainder the state during the January-March 2011-2012 climate season. This probabilistic shift in precipitation possibly reflects a return to atmospheric conditions normally associated with La Niña.